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Risk and Loss Aversion, Price Uncertainty and the Implications for Consumer Search

Adriaan R. Soetevent[1,2]
Tadas Bruzikas[1]

[1] *University of Groningen, The Netherlands;*
[2] *Tinbergen Institute, The Netherlands.*

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3062 PA Rotterdam
The Netherlands
Tel.: +31(0)10 408 8900
Fax: +31(0)10 408 9031

Risk and loss aversion, price uncertainty and the implications for consumer search

Adriaan R. Soetevent*
University of Groningen
Tinbergen Institute

Tadas Bružikas†
University of Groningen

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Abstract

Do the choices of consumers who search for a product's best price exhibit risk neutral, risk averse or loss averse risk attitudes? We study how in a problem of sequential search with costless recall the relation between a consumer's willingness to pay for continued search and the level of price uncertainty depends on her risk preferences. Independent of the current best price, an increase in price uncertainty encourages continued search when consumers are risk neutral. However, we prove that theory predicts an inversion when consumers are either risk or loss averse. In those cases, an increase in price uncertainty only increases the consumer's willingness to pay (WTP) for continued search if the current best price is sufficiently low.

We subsequently use this observation in an empirical test to identify between different risk preferences in a stylized problem of sequential search. In line with the inversion, we find that a reduction in price uncertainty decreases the WTP for continued search when the current best price is low but increases the WTP when it is high. While at odds with the assumption of risk neutrality, this finding is consistent with models of consumer risk and/or loss aversion. Moreover, the model parameters of risk and loss aversion that lead to the best empirical fit have values similar to those estimated for other decision domains.

JEL classification: D11, D12, D83, M31
Keywords: consumer search, risk aversion, loss aversion, price uncertainty

1 Introduction

Do the choices of consumers who search for a product's best price exhibit risk-neutral, risk averse or loss averse risk attitudes in the money dimension? In current research in industrial organization, two approaches to modeling risk preferences co-exist. In studies where consumer risk attitudes are not central to the analysis, consumers are simply assumed to be risk neutral with the decision to

*Corresponding author: University of Groningen, EEF, P. O. Box 800, 9700 AV Groningen, The Netherlands, a.r.soetevent@rug.nl.

†University of Groningen, EEF, P. O. Box 800, 9700 AV Groningen, The Netherlands, t.bruzikas@rug.nl.

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search being the outcome of a rational cost-benefit analysis.[1] A second, more recent strand of literature enriches the modeling of consumer preferences with elements from behavioral economics such as reference dependent preferences and loss aversion. In this approach, consumers are assumed to experience gain-loss utility relative to a reference point with the losses having a higher impact on consumer well-being than equivalent gains.[2]

The literature thus postulates either risk-neutrality or loss-aversion at the demand side and focuses on the implications for the design of optimal price distributions by profit-maximizing firms. Probably due to its emphasis on equilibrium price distributions, two issues have remained relatively unexplored. First, direct empirical evidence on how risk attitudes influence the decisions of agents in stylized situations of sequential search by considering actual choices is lacking.[3] Most of the existing evidence is indirect in the form of observed price distributions that can only be an equilibrium outcome in a model in which consumers are not risk neutral. We believe that additional justification for the modeling assumptions in the form of direct evidence is useful. We provide such evidence and test whether findings on risk and loss aversion can be extrapolated to the task domain of price search.

Second, no models in sequential search explicitly study how risk aversion instead of loss aversion affects a consumer's reservation price strategies. As we will elaborate below, the neglect of risk aversion – in favor of loss aversion – is to some extent justified both by theoretical arguments and by indirect evidence derived from observed price distributions. However it would be comforting to have direct evidence that models with loss aversion fit empirical data on actual search decisions at least as well as competing models that incorporate risk aversion. We aim to provide such evidence by deriving the theoretical implications of different risk attitudes (risk neutrality, risk aversion and loss aversion) on an agent's willingness-to-pay (WTP) for continued search in a simple problem of sequential search. We subsequently present stylized versions of this problem to empirical subjects and evaluate which of the models best fits the data. We show how the relation between the WTP for continued search and the variance of the price distribution is dependent on the consumer having risk neutral, risk averse or loss averse preferences. More specifically, we prove that when prices are normally distributed and the consumer is risk neutral, a mean-preserving reduction in the variance decreases the WTP to sample again, independent of the currently observed best price. In contrast, for risk- and loss averse

[1] E.g. Janssen and Shelegia (2015); Haan and Moraga-Gonzalez (2011).

[2] E.g. Heidhues and Kőszegi (2014) incorporate loss aversion in the money/price (and product) dimension to explain the empirical phenomenon of regular sales. Herweg and Mierendorff (2013) use consumer loss-aversion to explain the wide use of flat-rate tariffs. Other recent examples of IO studies with gain-loss utility in the price dimension are Carbajal and Ely (2016); Karle and Peitz (2014); Karle, Kirchsteiger and Peitz (2015).

[3] Schunk and Winter (2009) is an exception.

consumers, this positive correlation only holds when the current best price is sufficiently low.

Our approach and presentation differs in two ways from studies on search in IO that commonly consider equilibrium price distributions. Throughout, we take the price distribution as exogenously given. This allows us to focus on the decision-making problem of a consumer who currently observes a price and has to decide whether or not to sample again from a given distribution.[4] Also, most studies on search impose a fixed and constant search cost per sample and, conditional on this cost, derive the buyer's reservation price. That is, once the buyer samples a price lower than or equal to his reservation price, he will stop searching and purchase. We instead will condition on the currently observed best price and derive how much the consumer is willing to pay for another price observation. This presentation is primarily motivated by our empirical implementation in which we ask subjects to state how much they are willing to pay for another sample. As we shall illustrate, for all assumptions made on consumer risk preferences, there is a simple monotonic relation between the WTP and the reservation price.[5]

As said, the literature on search is remarkably void of theoretical models with risk-averse expected utility maximizing consumers.[6] There seem to be two main reasons for the absence of risk aversion in search theory. First, the focus in this field is on the (mixed-strategy) equilibrium price distributions that result from different underlying models of consumer decision making than on studying the actual decisions of consumers who are in a price search situation. Models that assume loss averse consumers are able to generate rich equilibrium price distributions with discontinuities that offer an explanation for important characteristics of empirically observed price patterns, such as sales (Heidhues and Kőszegi, 2014). In turn, the fact that such price patterns are observed is indirect evidence for the presence of loss averse consumers. Lacking the kink in the utility function at the reference point, models with risk averse consumers have much less interesting implications for equilibrium price distributions. Second, the search cost and the price of the goods considered are usually modest compared to the searching consumer's wealth. Combined with the forceful argument by Rabin (2000) and Rabin and Thaler (2001) that expected utility theory should be abandoned as an explanation for risk aversion over modest stakes, this has been an important motivation for theorists to focus on loss aversion and not risk aversion as the relevant risk attitude to study.

[4] Carlson and McAfee (1983) also assume a price distribution that is unrelated to the equilibrium distribution.

[5] The willingness-to-pay is sometimes also called the *ex ante* compensating variation, since it indicates how much a buyer who initially faces a (in our case, degenerate) price distribution F is willing to pay to replace F with another distribution G. That is, for a consumer endowed with income m and an indirect utility function $V(\cdot)$, the WTP s^* is the solution to the equation: $\int V(p)dF = \int V(p, m-s)dG$ (see Schlee, 2008).

[6] We ignore the literature on insurance markets in which risk aversion of course plays an important role.

At first sight, one may believe that results in contributions that do not make any assumptions at all on the underlying risk preferences encompass the case with risk-averse agents. An example is Stahl (1989) where buyers continue sampling observations as long as the expected consumer surplus exceed the cost of search.[7] However, as Stennek (1999) and Schlee (2008) have pointed out, expected consumer surplus as a measure of a buyer's willingness to pay to for another price observation is problematic in case the buyer is not risk neutral in the money dimension. Because of its elegance and relatedness to the problem we study in the present paper, we quote Stennek's (1999, p. 266) exposition of this problem in full:

> "Consider a consumer with an income, m, who has a unit demand for the commodity, and a willingness to pay $\alpha \leq m$. Hence, there are no income or price effects. Assume that the price is stochastic, but that $p \leq \alpha$. The residual income $m - p$ is spent on a composite commodity with a unitary price. Since the consumer always consumes one unit of the good, his ordinal utility can be measured by his consumption of the composite good, that is $m - p$. If the consumer dislikes variations in the consumption of the composite good (utility is a concave function of $m - p$), the consumer is risk-averse with respect to variations in residual income. Hence, a mean-preserving reduction in the variance of the price would increase the consumer's welfare. The consumer's surplus is defined as the area under the demand function above the price line, that is $\alpha - p$. Let Ep denote the expected price, then the expected consumer's surplus is $\alpha - Ep$, which is independent of price dispersion. That is, relying on the consumer's surplus, one would falsely conclude that the consumer does not value a stabilization of the price at its mean."

This paper proceeds as follows. Section 2 introduces our stylized problem of sequential search with costless recall. We show how the relation between the WTP for continued search and the variance of the price distribution is dependent on the consumer having risk neutral, risk averse or loss averse preferences. In Section 3, we use this result in our identification strategy to separate choices consistent with risk neutral risk attitudes from choices indicative of risk and/or loss averse risk attitudes in the price dimension. We elicit the WTP of over 300 individuals who each face four situations that differ in whether the current best price and the price variance is either high or low. The results of this non-incentivized experiment show support for the specifications with risk or loss aversion.[8] Both models have a good fit with the data for parameter values of risk and loss aversion, respectively, similar to

[7] We thank Alexei Parakhonyak for directing our attention to this issue. The final section of Kohn and Shavell (1974) also considers the impact of risk aversion on the decision to continue search.

[8] For evidence on stated preferences being similar to revealed preferences, see e.g. Kesternich et al. (2013).

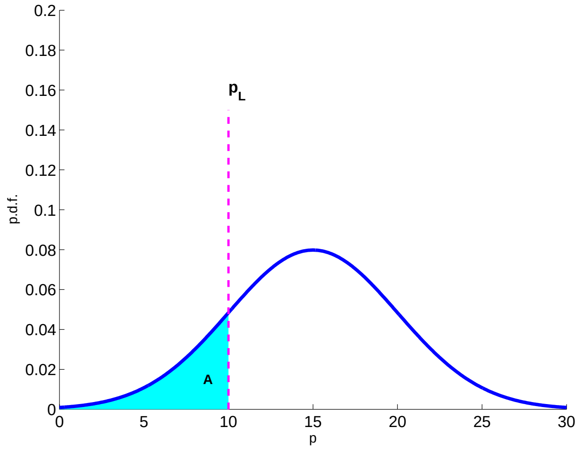
those estimated in other decision domains. This is reassuring because it justifies recent efforts in industrial economics to develop theory that shows how alternative risk-attitudes by buyers impact equilibrium price distributions.

2 Price uncertainty and search

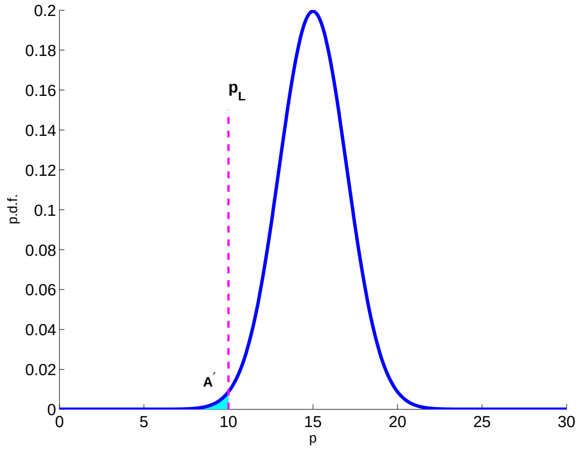
The stylized version of the decision problems that we present to our subjects is as follows. Figure 1 shows four combinations of price distributions and current best prices. Panels *a* and *c* show distributions with high price variation σ_H whereas the variance is low (σ_L) in panels *b* and *d*; in panels *a* and *b* the current best price is low (p_L) whereas in panels *c* and *d* it is high (p_H). In each of these cases, one can ask how much an agent, who currently observes price p_L or p_H, is willing to pay for one more draw from the given price distribution. This is a problem of sequential search with costless recall. As we formally show in Sections 2.1 to 2.3, it turns out that the prediction regarding the agent's WTP critically depends on whether the agent is risk neutral, risk averse or loss averse in the money dimension. For risk neutral agents, a reduction in price uncertainty reduces the expected benefits of continued search, both when the currently observed price p_L is low ($p_L < \mu$, a move from panel *a* to *b*), but also when the currently observed price p_H is high ($p_H > \mu$, a move from panel *c* to *d*).[9] Specifications that incorporate either risk aversion or loss aversion instead predict an inversion: the willingness to pay for continued search following a reduction in price variance decreases when the current best price is low but *increases* when this current best price is sufficiently high.

One reason to focus our design on how changes in price uncertainty affect search decisions are the different empirical implications for models with risk neutrality on the one hand and risk and loss aversion on the other hand. Another reason is that recent contributions in theory have established a connection between price uncertainty and the information provided to consumers about the common cost components of firms. One empirical example of a market where common cost components form a major determinant of prices and where firms can credibly inform consumers about these costs is the retail gasoline market. In this market, prices are to a great extent determined by the gasoline spot market price. Janssen *et al.* (2011) build on Stahl (1989) to incorporate cost uncertainty into the search literature. One of their results is that in a sequential search model with production cost uncertainty, the *ex ante* price uncertainty (as measured by the price spread) is higher when consumers are uninformed about the firms' cost realization, a situation similar to panels 1a and 1c. Janssen

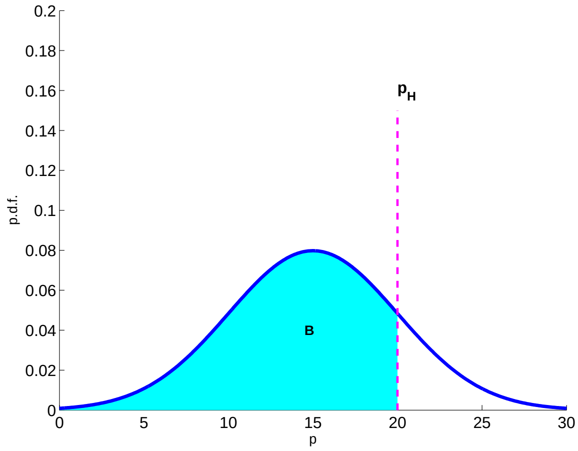
[9] How is this in search without recall? Well, in that case the agent stops searching iff. $p_1 \leq E[p] + s$. Clearly, since a change in σ does not alter either the left-hand side nor the right-hand side of this equation, a change in σ does not change the expected benefits of continued search.



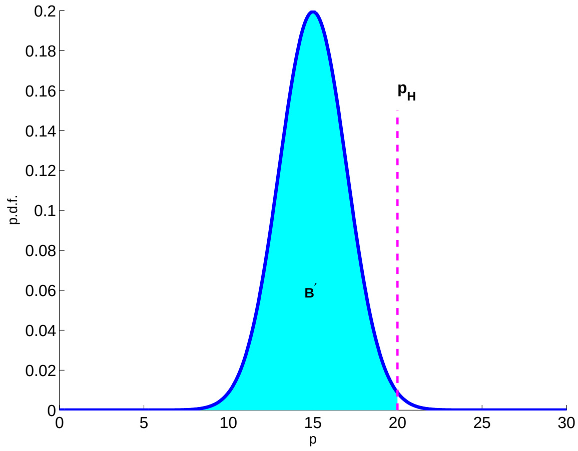
(a) Current price low, σ high.



(b) Current price low, σ low.



(c) Current price high, σ high.



(d) Current price high, σ low

Figure 1: A price distribution with high (panels a and c: $N(15, 5)$) and low (b and d: $N(15, 2)$) price variation. The currently observed price is either low (a and b: $p_L = 10$) or high (c and d: $p_H = 20$).

et al. (2011) also cite the pricing by gas stations as a motivation for their work, as does the earlier Benabou and Gertner (1993). In their models however, firms cannot give credible signals about the common cost and consumers have to infer this from the observed prices.[10] Whereas these studies study the implications for certain characteristics of the equilibrium price distributions, such as the price expectation and equilibrium price spread, our aim instead is to uncover how searching consumers actually respond to changes in price uncertainty.

Before we move on to the empirical application, we first state the theoretical results for that motivate the design of our test. Section 2.1 gives the empirical predictions for the case with risk-

[10] In other work (Bružikas *et al.*, 2016) we provide empirical evidence that in the Dutch retail gasoline market, firms do use their price boards to inform consumers about their recommended price. This recommended price closely follows fluctuations in the spot price of crude oil. Since this is an important cost component common to all firms, oil companies effectively inform consumers about the realization of a common cost component.

neutral consumers. Given that this is the default assumption in most studies, it is no surprise that the analytical results we present in this section are not new and have appeared elsewhere often in a different form and context. This section is followed by two others that presents results for the cases with risk- or loss-averse consumers. This approach and these findings are new.

2.1 Risk neutral consumers

Theories of sequential search with costless recall commonly assume that agents with unit demand for a good continue to search until the expected benefit of further search is smaller than the fixed cost s of sampling one more observation from a distribution $F(p)$ of prices charged by firms[11]. That is, the agent will stop searching if the currently observed best price p_1 satisfies the familiar condition:

$$p_1 \leq E[\min(p, p_1)] + s \qquad \text{or, equivalently} \qquad \int_0^{p_1} F(p)dp \leq s. \tag{1}$$

That is, an agent's optimal strategy is to continue search as long as the lowest price observed is greater than p^*, with p^* being the reservation price that is the solution to $\int_0^p F(p)dp = s$. Stated differently $s(p) = \int_0^p F(p)dp$ denotes the WTP for continued search when the current best price is p_1: the agent continues her search as long as $s(p) > s$.

An important step in arriving at this result is that the agent's utility is assumed to be linear in prices/wages. This effectively equates the objective of maximizing expected utility to the maximization of expected payoffs by a risk neutral agent.

Proposition 1 (Risk-neutral agents) *Suppose that prices are distributed $p \sim N(\mu, \sigma)$ and that this is common knowledge. Then, given a current best price $p_1 \in (0, \bar{p})$, with $\bar{p} \equiv F^{-1}(1 - F(0))$, the WTP for continued search $s(p_1) = \int_0^{p_1} F(p; \mu, \sigma)dp$ is increasing in σ for $p_1 > 0$.*[12]

Proof: All proofs are in the Appendix.

In other words, independently of the price currently observed, an increase in the value of σ (without changing μ) will increase the expected benefits of continued search to risk-neutral agents. This is what Bénabou and Gertner (1993, p. 83) dub the *variance effect*: "Given that buyers can return to the first store costlessly, an increase in the variance ... of the conditional distribution increases the option value of search." They already note that an increase in the unconditional variance of the common

[11] Stigler (1961); Rothschild (1973); Lippman and McCall (1976); Reinganum (1979); Weitzman (1979).

[12] Note that if, as we will do, μ and σ are chosen such that the probability of observing negative prices is zero, $F(0) = 0$, the upper bound $\bar{p} = +\infty$.

cost component leads to such an increase in the conditional variance. Also, the result of Proposition 1 appears for general distributions as a corollary in Kohn and Shavell (1974, p. 115).[13]

We will however show next this variance effect no longer holds in settings with risk-averse agents whose preferences are described by a CARA utility function.

2.2 Risk averse conumers

Consider a risk-averse agent with CARA risk preferences $u(w) = -\frac{1}{\gamma}e^{-\gamma w}$ (with w current wealth and $\gamma \in \mathbb{R}^+$) who observes price draws out of a $N(\mu, \sigma)$-distribution.[14] The agent has to decide between stopping and buying at the current best price or to search once more.[15] If the agent buys the product at the best price p_1 observed so far, her utility is

$$u(\text{Stop}|w - p_1; \gamma) = -\frac{1}{\gamma}e^{-\gamma(w-p_1)} \tag{2}$$

Her expected utility in case of continued search, paying a cost s for one more search, is

$$E[u(\text{Continue}|w - p - s; \gamma)] \quad = \quad -\frac{1}{\gamma}E[e^{-\gamma(w-p-s)}] \tag{3}$$

Equating (2) and (3) and solving for s via a number of manipulations (see Appendix A.2) leads to following proposition concerning the agent's maximum willingness to pay $s(p_1)$ to continue search:

Proposition 2 (Risk-averse agents) *Suppose that prices are distributed $p \sim N(\mu, \sigma)$ and that this is common knowledge. For a risk-averse agent with CARA risk preferences $u(w) = -\frac{1}{\gamma}e^{-\gamma w}$ (with w current wealth and $\gamma \in \mathbb{R}^+$ the Arrow-Pratt coefficient of absolute risk aversion), the willingness to pay $s(p)$ to sample one more observation when the best price encountered so far is p_1, equals:*

$$s(p_1) = p_1 - \frac{1}{\gamma}\left[\ln\left(\frac{1}{2}\right) + \ln\left\{e^{\gamma p_1}(1 - erf(x)) + e^{\gamma(\mu+\gamma\sigma^2/2)}(1 + erf(\tilde{x}))\right\}\right], \tag{4}$$

where $x \equiv (p_1 - \mu)/\sigma\sqrt{2}$ and $\tilde{x} \equiv (p_1 - \mu - \gamma\sigma^2)/\sigma\sqrt{2}$. Furthermore, there exists a unique price p_1^R such that

$$\frac{ds(p_1)}{d\sigma} > 0 \quad (< 0) \ \textit{if} \ \ p_1 < p_1^R \quad (p_1 > p_1^R).$$

[13] Their Corollary 20 reads: "If the utility function is linear, a mean-preserving increase in risk can only raise the switchpoint level of utility." The agent will stop searching if and only if the utility of the best price is higher than the switchpoint level.

[14] In all situations we consider, the agent buys the good so we submerge the gross utility of consuming the good in w.

[15] Note that with risk averse agents, it is important to impose that continued search implies only one more draw, because, as pointed out by Kohn and Shavell (1974, p. 114), even for risk averse agents the option value of search may increase following a mean-preserving increase in risk if they are allowed to sample many times.

For $\tilde{x}$ close to 0, p_1^R is approximated by

$$\hat{p}_1^R = \mu + \sigma\sqrt{(\gamma\sigma)^2 - \gamma\sigma\sqrt{2\pi} + 2}.$$

Proposition 2 shows an inversion in the response to changes in price uncertainty: a reduction in price uncertainty will decrease the option value of searching once more for risk averse consumers whose current best price is sufficiently low. For risk averse consumers for whom the current best price however is at the high end of the price distribution the option value of one more search will increase following a decrease in price uncertainty. The intuition is that in a situation of large price uncertainty, especially agents whose current best price is high can potentially receive a much better price by searching once more. However, risk aversion has the effect of lowering the utility associated with larger gains. Therefore, for risk averse consumers whose current best price is high, the option value to continue search is higher after a mean-preserving reduction in the variance of the price distribution because in expected utility, the decreases the probability of large gains are outweighed by the increases in the probability of small gains. The result also shows that if the current best price is sufficiently low, the latter effect can no longer compensate for the negative impact of the former.[16]

2.3 Loss averse consumers

Next we consider the case with loss averse agents. Following Kőszegi and Rabin (2007), the agent's utility is now specified as $u(w|r) \equiv m(w) + \mu\,(m(w) - m(r))$ with w a wealth level and r a reference wealth level. The first term $m(w)$ denotes a reference independent consumption utility. The second term is the gain-loss utility function, which reflects that the agent experiences a loss (gain) when her outcome is less (more) than the reference level. We will assume that consumption utility is linear, $m(w) = w$, and use the common piecewise linear specification of the gain-loss function:

$$\begin{cases} \eta(w-r) & \text{if} \quad w > r; \\ \eta\lambda(w-r) & \text{if} \quad w \leq r. \end{cases} \tag{5}$$

In this expression, η is a weight that reflect the relative importance of gain-loss utility to the agent compared to consumption utility. Throughout, we normalize the weight on gains by setting $\eta = 1$. This is a common approach and without loss of much generality. $\lambda \geq 1$ is the parameter of loss aversion. Loss-neutrality corresponds to $\lambda = 1$. We assume that the agent takes the current best price as the reference point with respect to which gains and losses are evaluated: $r = p_1$. There

[16] We leave it to future work to prove this for other distributions. Kaplan and Menzio (2015) find that empirical price distributions typically are symmetric and unimodal but leptokurtic, that is, having thicker tails and more mass around the mean than a Normal distribution with the same mean and variance. We believe that adding the latter properties to our model would not change our findings while considerably complicating the analysis.

is no consensus in the literature on how reference points with respect to prices are formed. As in Zhou (2011), we assume the the agent takes the current best price as her reference point. This seems reasonable: the agent experiences a loss if she ends up paying net more (including the search cost) after having searched one more shop than when she would have decided to stop searching and buy at price p_1. Finding a price that is sufficiently low that the cost of search are covered leads to a gain. One interpreration is that "no search" is the status quo that serves as the agent's reference point.[17]

The loss averse agent compares the net benefit of buying at the current best price $u(\text{Stop}|p_1) = w - p_1$ with the utility from continued search. The latter is the sum of expected consumption utility plus the expected value of the gain-loss value function:

$$\begin{aligned} u(\text{Continue}|p_1) \quad = \quad & w - p_1 - s + P(p \leq p_1)E[p_1 - p|p \leq p_1] + \eta \left[P(p \leq p_1 - s)E[p_1 - p - s|p \leq p_1 - s] \right. \\ & \left. -\lambda \left\{ P(p_1 - s < p \leq p_1)E[p - p_1|p_1 - s < p \leq p_1] + sP(p > p_1 - s) \right\} \right]. \end{aligned}$$

The first term, $v - p_1 - s + P(p \leq p_1)E[p_1 - p|p \leq p_1]$, reflects consumption utility: the agent's net wealth after search is $w - p_1 - s$ in case the search does not lead to a better price. However, with probability $P(p \leq p_1)$, the agent observes a price lower than p_1 with the expected price differential in that case being equal to $E[p_1 - p|p \leq p_1]$.

Note that we assume that the search cost is part of the gain-loss utility: the agent only experiences a gain if searching results if is leads to a price sufficiently low to fully recoup the cost of search, which happens with probability $P(p \leq p_1 - s)$. In all other cases the search cost is not or only partly made up for by a better price deal. Again, we derive the WTP for continued search $s(p_1)$ by equating $u(\text{Continue}|p_1)$ and $u(\text{Stop}|p_1)$ and solving for s. Doing so leads to the following result:

Proposition 3 (Loss-averse agents) *Suppose that prices are distributed $p \sim N(\mu, \sigma)$ and that this is common knowledge. For a loss-averse agent with loss-aversion parameters λ and η who takes the best price encountered so far, p_1, as her reference point, there exists a unique price price p_1^L such that:*

$$\frac{ds(p_1)}{d\sigma} > 0 \quad (< 0) \text{ if } p_1 < p_1^L \quad (p_1 > p_1^L),$$

with $s(p_1)$ the willingness to pay to sample one more observation. In the limit, $\lim_{\lambda \downarrow 1} p_1^L = \infty$.

Proposition 3 proves that qualitatively, we have a similar inversion as in the model with risk aversion. Other than for the model with risk-aversion, we cannot derive an analytical expression for $s(p_1)$ in

[17] We are aware of possible alternative choices here, such at the expectation-based reference points developed by Köszegi and Rabin (2006).

terms of the fundamental model parameters. We can however show that $\frac{ds^*}{d\sigma} > 0$ when p_1 exceeds a unique critical threshold value p_1^L. In the limit to loss-neutrality ($\lambda \downarrow 1$), this threshold value goes to infinity such that $\frac{ds^*}{d\sigma} > 0$ for all values of p_1, as in Proposition 1.

2.4 Empirical implications

A comparison of Proposition 2 and 3 shows that if the best price observed so far is sufficiently high, risk and loss aversion generate the same qualitative prediction that the willingness to continue search is decreasing in σ. The numerical examples in Table 1 provide some additional insight. Based on the discrete distributions that we will use in our empirical analysis (Section 3), the table shows for different values of the parameters of risk and loss aversion (γ and λ, respectively) the maximal WTP for continued search.[18]

Let's focus on the case where the current best price is high, $p_1 = 20$. At levels of risk aversion commonly found in the empirical studies measuring risk aversion using a CARA specification ($\gamma \approx 0.10$ see e.g. Von Gaudecker *et al.*, 2011) the WTP for continued search is higher in the low variance case than in the high variance case (4.80 vs. 4.55). The same holds for the model with loss aversion for the commonly found estimates of the loss aversion coefficient of $\lambda \approx 2.25$ (see e.g. Tversky and Kahneman, 1992; Abdellaoui *et al.*, 2007; Engström *et al.*, 2015) (4.52 vs. 4.61).

Figure 2 shows the relation between the search cost s and the reservation price r for the different risk attitudes, using $\gamma = 0.10$ and $\lambda = 2.25$ for risk and loss aversion, respectively. In all cases, the relation is monotone with the reservation price increasing in the cost of search. In line with Propositions 1 to 3, for any given search cost s, the reservation price for the high variance case is lower than for the low variance case in case of risk neutrality whereas for risk averse and loss averse risk preferences, the inversion is observed. A comparison of panels 2b and 2c also shows in this setting and for the values $\gamma = 0.10$ and $\lambda = 2.25$, risk and loss aversion have very similar implications: both for the situation with low variance as for the one with high variance, the relation between the search cost and reservation price is almost identical. This implies that while our design is able to distinguish between risk neutrality on the one hand and risk/loss aversion on the other, it is not very suitable to separately identify risk and loss aversion.

Future research could use the fact that, as shown in Table 1, the gap in WTP between the low and high variance case grows faster under risk aversion. The table shows that the main cause of this difference is that under risk aversion, the WTP in the high variance case is decreases relatively fast as

[18] Using instead the continuous distributions from Figure 1 leads to a very similar table.

Table 1: WTP for continued search under risk aversion (CARA exponential utility $u(z, \gamma) = -\frac{1}{\gamma} e^{-\gamma z}$) and loss aversion (linear gain-loss utility with weight $\eta = 1$).

	WTP - Risk Aversion (CARA)					WTP - Loss Aversion			
p_1	10	10	20	20		10	10	20	20
σ	High	Low	High	Low		High	Low	High	Low
γ					λ				
0.00	0.33	0.01	5.33	5.01	**1.00**	0.33	0.01	5.33	5.01
0.01	0.33	0.01	5.25	4.99	**1.20**	0.30	0.01	5.17	4.94
0.05	0.31	0.01	4.92	4.91	**2.00**	0.23	0.01	4.64	4.69
0.10	0.29	0.01	4.55	4.80	**2.25**	0.21	0.01	4.52	4.61
0.20	0.25	0.01	3.88	4.60	**3.00**	0.18	0.01	4.15	4.45
0.30	0.23	0.01	3.35	4.40	**3.50**	0.16	0.00	3.96	4.34
0.40	0.20	0.01	2.92	4.20	**5.00**	0.12	0.00	3.52	4.09
0.50	0.19	0.01	2.58	4.01	**9.00**	0.08	0.00	2.79	3.68

γ increases[19]. The reason for this difference is that in the specifications we use, we have a linear gain-loss function while in the risk-averse case, the benefits of search enter the expected utility function in a non-linear fashion. This has the effect that the potentially high benefits from search induced by high price uncertainty receive relatively less weight in the latter case. The small number of four observations per respondent does not allow us to estimate the parameters of risk and loss aversion at the individual level.

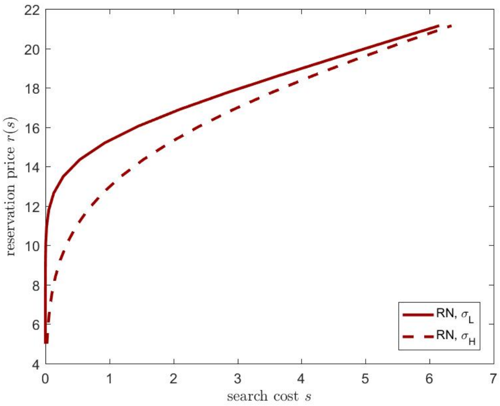
3 Experimental evidence

3.1 Design

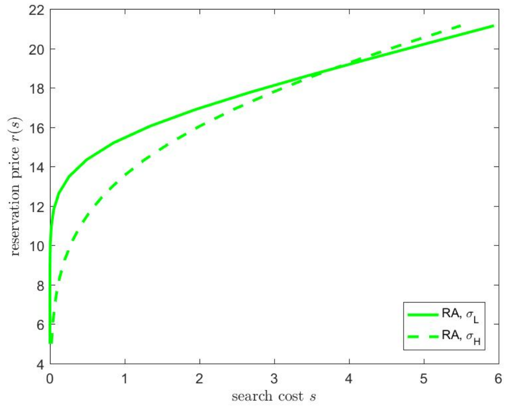
As part of their weekly tutorial 337 first-year students at the Department of Economics at the University of Groningen were exposed to four different choice situations that emulate those shown in Figure 1. For each situation, they had to answer how much they would be willing to pay to see the price of a second firm.[20] The students were all enrolled in an the undergraduate program at the department. The majority (182) were first-year students in Economics and Business Economics (E&BE). Another 83 were enrolled in the program Econometrics and Operations Research (EOR), a program that traditionally attracts students with well-developed quantitative skills. Fifty-five students were enrolled in the so-called pre-MSc program. This is a one-year program designed for students with a non-economics BSc to prepare for a MSc in Economics. The remaining seventeen students were enrolled in the Finance program.

[19]Compare e.g. the case with $\gamma = 0.50$ and $\lambda = 5.00$: for $p_1 = 20$, the WTP is similar when $\sigma = \sigma_L$, 4.01 vs. 4.09, but considerably different when $\sigma = \sigma_H$, 2.58 vs. 3.52.

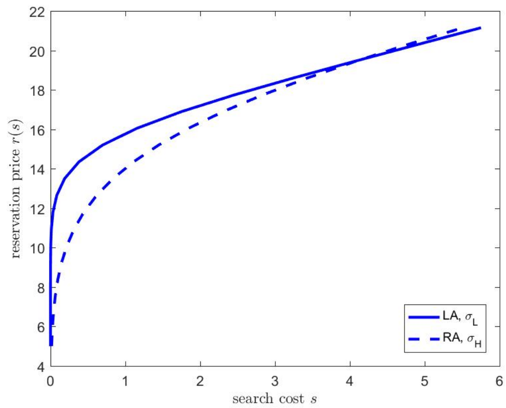
[20]See Appendix C for the exact layout and wording of the survey.



(a) Risk neutrality.

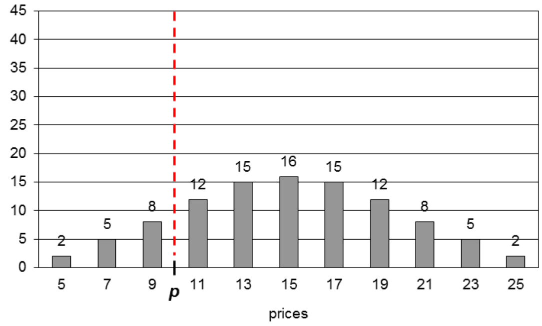


(b) Risk aversion ($\gamma = 0.10$).

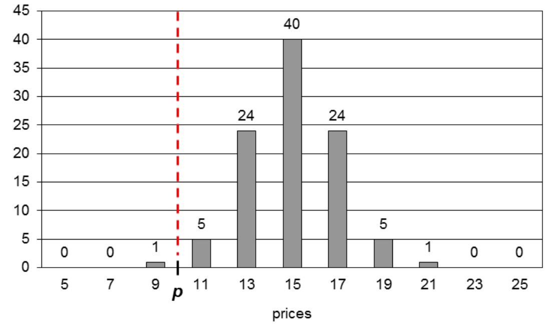


(c) Loss aversion ($\lambda = 2.25$).

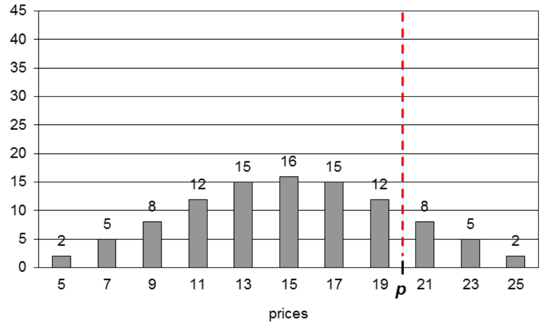
Figure 2: Relation between the search cost s and the reservation price $r(s)$ for consumers with risk neutral (panel a), risk averse (panel b), and loss averse (panel c) risk attitudes.



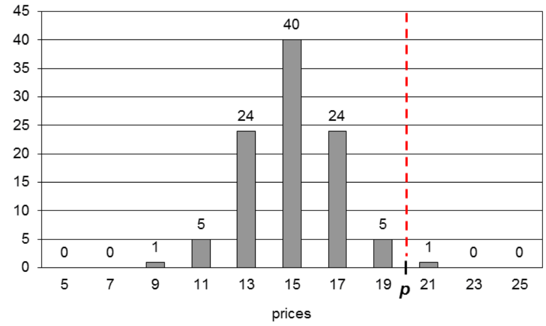
(a) Situation 1: $p_L = 10$, $\sigma_H = 4.60$ high.



(b) Situation 2: $p_L = 10$, $\sigma_L = 2.06$ low.



(c) Situation 3: $p_H = 20$, $\sigma_H = 4.60$ high.



(d) Situation 4: $p_H = 20$, $\sigma_L = 2.06$ low.

Figure 3: Overview of the four situations presented to respondents. The bars denote the number of firms that charges a given price ($\mu = 15$ in all cases).

In order to ensure that students had no problems in understanding the price distributions, we used discrete price distributions in the experiment. These distributions are shown in Figure 3. They have a mean ($\mu = 15$) and variance ($\sigma_L = 2.06; \sigma_H = 4.60$) that closely mimic the ones in Figure 1. By using discrete distributions, there was no need for participants to have an intimate knowledge of probability density functions, normally distributed variables, variance etc. Subjects who would like to do so, could relatively easily calculate the expected benefits of continued search. They just had to calculate for each price lower than the current best price the difference with the current price, to multiply this difference with the probability of finding the lower price and sum the results. We refer to the four choice situations in Figure 3 as (p_L, σ_H), (p_L, σ_L), (p_H, σ_H), and (p_H, σ_L), respectively.

Each student was presented with all four situations on five stapled pages. To rule out order effects, we randomized the order in which the situations were presented.[21] The first page contained the following information: "Please consider the situations on the following four pages and answer the question that follows the descriptions." Each panel on the pages 2 to 5 was accompanied by a brief

[21]The four possible orders were: $p_L s_H - p_L s_L - p_H s_H - p_H s_L$; $p_L s_L - p_L s_H - p_H s_L - p_H s_H$; $p_H s_H - p_H s_L - p_L s_H - p_L s_L$; $p_H s_L - p_H s_H - p_L s_L - p_L s_H$. Table B.1 shows for the final sample for each particular order the number of observations per program.

explanatory text and the question how much they were willing to pay for one additional search. To give an example, the text for situation (p_L, σ_H) was as follows:

> "You wish to buy a certain product. The firm you have just visited offers this product at a price of €10. There are 100 other firms that offer exactly the same product. You know that two of these firms charge a price of €5, five charge a price of €7, eight charge a price of €9 etc. This information is summarized in the figure above (the current price of €10 is shown by the dotted vertical line). Unfortunately you don't know which firm charges what price.
>
> Now you have to decide:
>
> a) buy the product from the firm you have just visited at this firm's price of €10.
>
> b) pay an amount to visit one randomly selected firm out the 100 other firms to see whether this firm offers you the product at a better price.
>
> Important note: If you choose **b)**, you still have to the option to buy the product at €10 from the first firm, should the second firm be more expensive. If the second firm charges a price lower than €10, you can of course buy the product at this lower price.
>
> What is the maximum amount you would be willing to pay to see the price of a second firm? [please fill in a non-negative number with two digits]
>
> €_______"

Students were free to move forward and back between pages and to change their answers if they deemed this necessary.

3.2 Results

Of the 337 subjects, 29 did not give an answer to any of the four situations. Another 15 students completed one to three situations.[22] We decided to drop all 44 observations. One other subject provided answers in the range €100 to €300. Possibly, this subject has answered the questions in cents instead of euro's but there was no way to verify this. For this reason, we decided to drop all observations of subjects who – for one or more of the situations – indicated a willingness to pay for search that exceeded the price observed at the current shop. This reduced the number of observations

[22] Six persons answered three questions; five answered two and four answered one. With 4.8%, the dropout rate from the EOR sub-sample is considerably lower than for the other majors (14.8% for E&BE, 16.4% for Pre-MSc, and 23.5% for Finance). This is because students of the latter majors were asked to complete this non-obligatory survey after their weekly tutorial test and may therefore have been less willing to participate because of their – literally – outside option. However, we have no reason to suspect that the participation decision is correlated with our outcomes of interest.

Table 2: Summary statistics respondents.

			age		grade	
Programme	obs.	% female	mean	s.d.	mean	s.d.
Economics and Business	146	30.4	19.33	1.35	6.74	1.50
Econometrics	79	31.6	19.05	1.45	6.39	1.40
Pre-MSc	46	33.3	23.67	1.71	7.00	1.31
Minor Finance	12	30.0	22.24	1.73	7.00	1.76
Total	**283**	**31.2**	**19.92**	**2.16**	**6.67**	**1.46**

Notes: Econometrics students follow a different Microeconomics course than the other three groups. The statistics of the econometrics students are for all students who took the exam and slightly differ from the sample of students who completed the survey (85 vs. 79 obs.).

by ten such that our final data set includes 283 observations. Background characteristics of these individuals are provided in Table 2.

The expected benefits of continued search are €0.33 in (p_L, σ_H); €0.01 in (p_L, σ_L), €5.33 in (p_H, σ_H), and €5.01 in (p_H, σ_L). Based on this, a risk neutral agent would indicate $WTP(p_L, \sigma_H) > WTP(p_L, \sigma_L)$ and $WTP(p_H, \sigma_H) > WTP(p_H, \sigma_L)$. However, Table 3 shows that is not what we find in the data. When the best price observed so far is at the lower end ($p_L = 10$), respondents do indicate an on average higher WTP when the variance of the price distribution is higher, €0.83 vs. €0.46 (p-value < 0.0001, paired t-test, unless stated otherwise). This is in line with the theoretical predictions for risk neutral agents. In both cases, the average WTP exceeds the expected benefits of search, with €0.50 and €0.45, respectively, but this difference is not significant ($p = 0.438$).

However, when the best price observed so far is at the high end ($p_H = 20$), the average WTP for continued search is €4.92 when the price variation is high and €5.15 when this variation is low ($p = 0.154$). Moreover, while the WTP/expected benefits gap is still positive for the low variance case (€0.144), it is negative (-€0.406) for the high variance case and this difference is statistically significant ($p = 0.0007$). In other words, at odds with risk neutrality but in line with the alternative hypotheses of risk aversion and loss aversion, the respondents' average WTP is decreasing in price variation when the currently observed price is high.[23]

Table 4 considers decisions at the level of the individual subject and provides further support for our main finding. The table shows that when the current best price is low, almost no subjects (1.4%) indicate a higher WTP for continued search when the price variation is low. In contrast, when the current best price is high, 40.6% of all subjects indicates a higher WTP when price uncertainty is low instead of high. To see whether the WTP/expected benefit-gap is related to any observable charac-

[23]The difference of -€0.406 and 0 has a p-value of 0.107 (one-sided t-test).

Table 3: Summary Statistics

p	10	10	20	20
σ	High	Low	High	Low
Exp. benefits search	0.33	0.01	5.33	5.01
mean WTP	0.830	0.456	4.924	5.154
	(0.118)	(0.109)	(0.251)	(0.251)
WTP/Exp. Benefit gap	0.500	0.446	-0.406	0.144
obs.	283	283	283	283

Note: Standard errors in parentheses.

Table 4: Ranking of willingness to pay on the subject level

		$WTP(p_L, \sigma_H) \gtreqless WTP(p_L, \sigma_L)$				
		>	=	<		
$WTP(p_H, \sigma_H) \gtreqless WTP(p_H, \sigma_L)$	>	31	37	2	**70**	**24.7%**
	=	20	77	1	**98**	**34.6%**
	<	51	63	1	**115**	**40.6%**
		102	**177**	**4**	**283**	
		36.0%	**62.5%**	**1.4%**		

teristics, define the binary variable y such that $y = 1$ if WTP>Expected benefits and 0 otherwise. Table 5 shows for our four situation the results of a linear regression of this variable on the explanatory variables female, age and the grade the student eventually obtained for the introductory microeconomics course.[24] The results does not show that the propensity to indicate a WTP that exceeds the expected benefits of sampling once more is related to gender or age. The coefficients do show that the performance in the microeconomics course and the indicated WTP are negatively related in the situations with low price uncertainty.

4 Discussion: Risk or loss aversion in price search

Our empirical analysis shows clear support for the inversion of the response of the WTP for continued search to changes in price uncertainty. This result questions models of consumer search that assume that buyers act as risk-neutral agents who simply trade off between the expected benefits and costs.

Our theoretical derivations show that both the expected utility specification with risk averse agents as well as the prospect theory formulation with loss aversion predict the inversion we observe in our

[24] A number of notes: The students in econometrics are not included in this regression because we lacked identifying information to match their decisions with background characteristics and grades; Dutch grades are between zero and ten, with ten being the perfect score. The marginal effects of a probit regression look very similar to the presented linear regression estimates.

Table 5: Regression estimates (Dependent variable: $WTP - Exp.Benefit > 0$)

p	10	10	20	20
σ	High	Low	High	Low
female	-0.029	-0.057	-0.018	0.081
	(0.076)	(0.054)	(0.072)	(0.071)
age	-0.016	0.006	0.019	0.011
	(0.015)	(0.011)	(0.014)	(0.014)
grade micro	-0.008	-0.029*	-0.013	-0.052**
	(0.023)	(0.017)	(0.022)	(0.022)
constant	0.653*	0.201	-0.077	0.337
	(0.356)	(0.253)	(0.022)	(0.336)
R^2	0.011	0.03	0.014	0.043
obs.	*171*	*171*	*171*	*171*

Standard deviations in parentheses. ***(**,*) indicate statistical significance at the 1%-level (5%-level, 10%-level).

data. Moreover, the parameters of both risk and loss aversion that lead to a good fit are close to the values found in other empirical studies. In all, our findings show that price search is a decision task where consumer risk attitudes are relevant; they suggest that results from studies on loss aversion in other domains (such as endowment effects and tax compliance) have external validity for the domain of price search. This justifies the recent efforts in industrial economics to develop theories that show how alternative risk-attitudes by buyers impact equilibrium price distributions and can help to explain phenomena such as sales (e.g. Heidhues and Köszegi, 2014).

Our empirical evidence also adds to the debate on whether or not buyers of goods experience loss aversion in routine transactions. Tversky and Kahneman (1991) posit that there is no loss aversion in routine transactions because buyers expect the money outlays associated with the exchange of goods. However, in the theory developed by Bateman *et al.* (1997) there is symmetry between the act of giving up goods and of giving up money with both of them being construed as losses. The authors of these studies have engaged in an "adversarial collaboration" (Bateman *et al.*, 2005) to design an experiment to settle the debate. The findings of this experiment by and large support the hypothesis that money outlays are perceived as losses. However, in another study, Novemsky and Kahneman (2005) find conflicting evidence that money given up in routine purchases is not subject to loss aversion. Novemsky and Kahneman point to differences in the subject pools as a potential cause for the empirical discrepancy and call for additional evidence.[25] Our result support the view that money outlays do evoke loss aversion, also in the context of routine purchasing decisions.

That said, the empirical data that we collected and presented clearly are of an exploratory nature.

[25]Bateman *et al.*, (2005) uses UK subjects, Novemsky and Kahneman (2005) US subjects.

Although we believe that respondents did not have any reason to misstate their willingness to pay, they were not incentivized and each respondent only answered four simple questions. It is clear that a direct test of risk versus loss aversion asks for richer data which allows one to estimate mixture models to gauge the relative importance of both models (Harrison and Rutström, 2009) or to evaluate the models by fitting the parameters of the alternative models at the individual level (Hey and Orme, 1994). As argued by Harrison and Rutström (2009), there is the possibility that different behavioral processes co-exist with the risk attitude of some individuals being adequately fitted by expected utility and those of others by prospect theory. The current study is too limited to pursue this question in more depth but future research could fruitfully use the relation between the key model parameters and response to changes in the price variation to identify the relative importance of risk and loss aversion in price search.

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A Appendix

A.1 Proof of Proposition 1

First note that $F(p;\mu,\sigma)$ can be expressed as

$$F(p;\mu,\sigma) = \frac{1}{2}\left[1 + \operatorname{erf}\left(\frac{p-\mu}{\sigma\sqrt{2}}\right)\right] \tag{A.1}$$

with $\operatorname{erf}(x) = \frac{2}{\sqrt{\pi}}\int_0^x e^{-t^2}dt$ the Gauss error function. Note that $\operatorname{erf}(-x) = -\operatorname{erf}(x)$.
We aim to prove that for $p_1 \in (0,\bar{p})$ with $\bar{p} \equiv F^{-1}(1-F(0))$, $\frac{\partial}{\partial\sigma}\int_0^{p_1} F(p;\mu,\sigma_L)dp > 0,\ \forall\ p_1 \in (0,\bar{p}]$. From Leibniz' integral rule, we know that

$$\frac{\partial}{\partial\sigma}\int_0^{p_1} F(p;\mu,\sigma_L)dp = \int_0^{p_1}\frac{\partial F(p;\mu,\sigma_L)}{\partial\sigma}dp.$$

The derivative of $\operatorname{erf}(x)$ is equal to

$$\frac{d\operatorname{erf}(x)}{dx} = \frac{2e^{-x^2}}{\sqrt{pi}}. \tag{A.2}$$

Define $x \equiv \frac{p-\mu}{\sigma\sqrt{2}}$ such that

$$\frac{dx}{d\sigma} = -\frac{(p-\mu)\sqrt{2}}{2\sigma^2} = -\frac{(p-\mu)}{\sigma^2\sqrt{2}} = -\frac{x}{\sigma}. \tag{A.3}$$

Taken together, (A.2) and (A.3) imply that:

$$\frac{d\operatorname{erf}(x)}{d\sigma} = \frac{d\operatorname{erf}(x)}{dx}\cdot\frac{dx}{d\sigma} = -\frac{2xe^{-x^2}}{\sigma\sqrt{\pi}} \tag{A.4}$$

Also, using this result and equation (A.1),

$$\frac{\partial F(p;\mu,\sigma_L)}{\partial\sigma} = \frac{1}{2}\cdot\frac{d\operatorname{erf}(x)}{d\sigma} = -\frac{xe^{-x^2}}{\sigma\sqrt{\pi}}, \tag{A.5}$$

which is non-negative for $p \leq \mu$ and negative for $p > \mu$. Therefore, $\frac{\partial}{\partial\sigma}\int_0^{p_1} F(p;\mu,\sigma_L)dp > 0$ clearly holds for $p_1 \in (0,\mu)$. It also holds for $p_1 \in (\mu,\bar{p})$ because

$$\frac{\partial}{\partial\sigma}\int_0^{p_1} F(p;\mu,\sigma_L)dp = \frac{\partial}{\partial\sigma}\int_0^{\mu} F(p;\mu,\sigma_L)dp + \frac{\partial}{\partial\sigma}\int_\mu^{p_1} F(p;\mu,\sigma_L)dp > \int_0^{\bar{p}} F(p;\mu,\sigma_L)dp = 0.$$

This completes the proof. Figure A.1 visualizes the argument: Area B is always smaller than area A for $p_1 < \bar{p}$. $\square$.

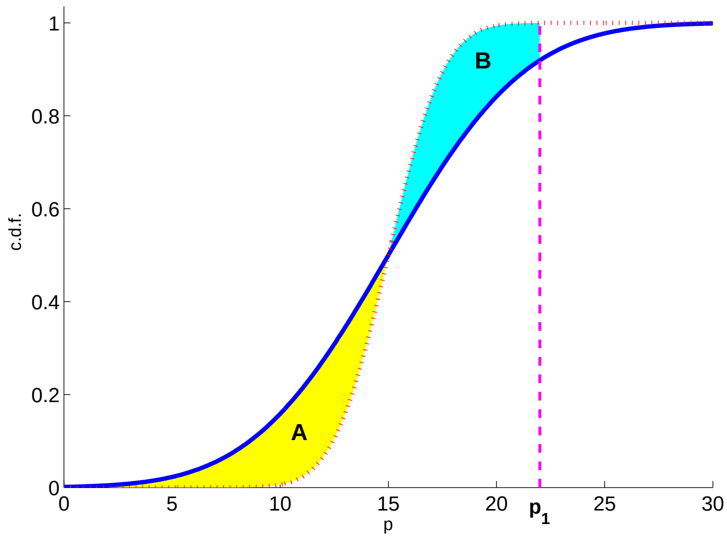

Figure A.1: The c.d.f. for $p \sim N(\mu, 5)$ (solid blue line) and $p \sim N(\mu, 2)$ (dotted red line) with $\mu = 15$.

A.2 Proof of Proposition 2

Consider a risk-averse agent with CARA risk preferences $u(w) = -\frac{1}{\gamma}e^{-\gamma w}$ (with w current wealth and $\gamma \in \mathbb{R}^+$) who observes price draws out of a $N(\mu, \sigma)$-distribution.[26] If the agent buys the product at the best price p_1 observed so far, her utility is

$$u(w;\gamma) = -\frac{1}{\gamma}e^{-\gamma(w-p_1)} \tag{A.6}$$

Her expected utility in case of continued search, paying a cost s for one more search, is

$$\begin{aligned}
E[u(w-p-s)] &= -\frac{1}{\gamma}E[e^{-\gamma(w-p-s)}] = -\frac{e^{-\gamma(w-s)}}{\gamma}E[e^{\gamma p}] \\
&= -\frac{e^{-\gamma(w-s)}}{\gamma}\left[P(p>p_1)e^{\gamma p_1} + P(p \le p_1)E[e^{\gamma p}|p<p_1]\right] \\
&= -\frac{e^{-\gamma(w-s)}}{\gamma}\left[(1-F(p_1))e^{\gamma p_1} + F(p_1)E[e^{\gamma p}|p<p_1]\right] \\
&= -\frac{e^{-\gamma(w-s)}}{2\gamma}\left[e^{\gamma p_1}\left\{1-\operatorname{erf}\left(\frac{p_1-\mu}{\sigma\sqrt{2}}\right)\right\} + e^{\gamma(\mu+\gamma\sigma^2/2)}\left[1+\operatorname{erf}\left(\frac{p_1-\mu-\gamma\sigma^2}{\sigma\sqrt{2}}\right)\right]\right]
\end{aligned} \tag{A.7}$$

To arrive at the final equality, observe that

$$(1-F(p_1)) = \frac{1}{2} - \frac{1}{2}\operatorname{erf}\left(\frac{p_1-\mu}{\sigma\sqrt{2}}\right)$$

[26] In all situations we consider, the agent buys the good so we submerge the consumption utility of the good in w.

and

$$F(p_1)E[e^{\gamma p}|p<p_1]=\int_0^{p_1}e^{\gamma x}f(x)dx=\int_0^{p_1}\frac{e^{\gamma x}}{\sigma\sqrt{2\pi}}e^{-(x-\mu)^2/2\sigma^2}dx=\frac{1}{\sigma\sqrt{2\pi}}\int_0^{p_1}e^{\frac{-(x-\mu)^2+2\gamma x\sigma^2}{2\sigma^2}}dx.$$

In turn, this equals

$$F(p_1)E[e^{\gamma p}|p<p_1]=e^{\gamma(\mu+\gamma\sigma^2/2)}\int_0^{p_1}\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{(x-(\mu+\gamma\sigma^2))^2}{2\sigma^2}}dx \tag{A.8}$$

because

$$\frac{-(x-\mu)^2+2\gamma x\sigma^2}{2\sigma^2}=-\frac{(x-\mu-\gamma\sigma^2)^2}{2\sigma^2}+\gamma(\mu+\gamma\sigma^2/2).$$

We use (A.1) to rewrite (A.8) as

$$F(p_1)E[e^{\gamma p}|p<p_1]=e^{\gamma(\mu+\gamma\sigma^2/2)}F(p_1;\mu+\gamma\sigma^2,\sigma)=\frac{e^{\gamma(\mu+\gamma\sigma^2/2)}}{2}\left[1+\operatorname{erf}\left(\frac{p_1-\mu-\gamma\sigma^2}{\sigma\sqrt{2}}\right)\right].$$

Equating (A.6) and (A.7) and solving for s via a number of manipulations leads to the expression in equation (4) for the agent's maximum willingness to pay s^* to continue search.

Next we wish to derive how the sign of $\frac{ds^*}{d\sigma}$ depends on p_1, the best price currently observed. In doing so, we use that $\tilde{x}\equiv\frac{p_1-\mu-\gamma\sigma^2}{\sigma\sqrt{2}}=x-\gamma\sigma/\sqrt{2}$ such that

$$\frac{d\tilde{x}}{d\sigma}=-\left(\frac{\tilde{x}}{\sigma}+\gamma\sqrt{2}\right) \tag{A.9}$$

and

$$\frac{d\operatorname{erf}(\tilde{x})}{d\sigma}=\frac{d\operatorname{erf}(\tilde{x})}{d\tilde{x}}\cdot\frac{d\tilde{x}}{d\sigma}=-\frac{2e^{-\tilde{x}^2}}{\sqrt{\pi}}\left(\gamma\sqrt{2}+\frac{\tilde{x}}{\sigma}\right) \tag{A.10}$$

Similarly, for $x\equiv(p_1-\mu)/(\sigma\sqrt{2})$, we have

$$\frac{d\operatorname{erf}(x)}{d\sigma}=-\frac{2xe^{-x^2}}{\sigma\sqrt{\pi}}; \tag{A.11}$$

The derivative of s^* (equation (4)) with respect to σ equals

$$\frac{ds^*}{d\sigma}=-\frac{1}{\gamma}\left[\frac{-e^{\gamma p_1}\frac{d\operatorname{erf}(x)}{d\sigma}+\left(\gamma^2\sigma(1+\operatorname{erf}(\tilde{x}))+\frac{d\operatorname{erf}(\tilde{x})}{d\sigma}\right)e^{\gamma(\mu+\gamma\sigma^2/2)}}{e^{\gamma p_1}(1-\operatorname{erf}(x))+e^{\gamma(\mu+\gamma\sigma^2/2)}(1+\operatorname{erf}(\tilde{x}))}\right]. \tag{A.12}$$

The denominator of (A.12) is non-negative and therefore, $\frac{ds^*}{d\sigma}=0$ only if the numerator is zero. We use (A.9) to (A.11) to rewrite

$$
\begin{aligned}
&e^{\gamma p_1}\frac{d\mathrm{erf}(x)}{d\sigma} - \left(\gamma^2\sigma(1+\mathrm{erf}(\tilde{x})) + \frac{d\mathrm{erf}(\tilde{x})}{d\sigma}\right) e^{\gamma(\mu+\gamma\sigma^2/2)} = \\
&-\frac{2xe^{\gamma p_1}e^{-x^2}}{\sigma\sqrt{\pi}} - \left(\gamma^2\sigma(1+\mathrm{erf}(\tilde{x})) - \frac{2e^{-\tilde{x}^2}}{\sqrt{\pi}}\left[\frac{x}{\sigma}+\frac{\gamma}{\sqrt{2}}\right]\right) e^{\gamma(\mu+\gamma\sigma^2/2)} = 0
\end{aligned}
$$

Multiply both sides with $-e^{-\gamma(\mu+\gamma\sigma^2/2)}$ to obtain

$$
\begin{aligned}
&\frac{2x}{\sigma\sqrt{\pi}}\left[e^{\gamma(p_1-\mu-\gamma\sigma^2/2)-x^2} - e^{-\tilde{x}^2}\right] - \frac{2\gamma e^{-\tilde{x}^2}}{\sqrt{2\pi}} + \gamma^2\sigma(1+\mathrm{erf}(\tilde{x})) \\
= \quad & 0 - \frac{2\gamma e^{-\tilde{x}^2}}{\sqrt{2\pi}} + \gamma^2\sigma(1+\mathrm{erf}(\tilde{x}))
\end{aligned}
$$

Define $G(\tilde{x}) \equiv \frac{1}{2}(1+\mathrm{erf}(\tilde{x})) - \frac{1}{\gamma\sigma\sqrt{2\pi}}e^{-\tilde{x}^2}$. So, $ds^*/d\sigma = 0$ if $G(\tilde{x}) = 0$. Note that $G(\cdot)$ is continuous in $\tilde{x}$. We prove that there is one unique $\tilde{x}$ for which $G(\tilde{x}) = 0$ by showing that:

i $\lim_{\tilde{x}\to-\infty} G(\tilde{x}) = 0$, $G(\tilde{x}) < 0$ for $\tilde{x}$ sufficiently small, and $\lim_{\tilde{x}\to\infty} G(\tilde{x}) = 1$;

ii $dG(\tilde{x})/d\tilde{x} = 0$ has one unique solution $\check{x}$ and that $G(\check{x})$ is decreasing (increasing) for $\tilde{x} < (>)\check{x}$.

Together *i*) and *ii*) imply that the value of $\tilde{x}$ for which $G(\tilde{x}) = 0$ must be larger than $\check{x}$ and unique.

The proof of *i*) is immediate using the definition of $G(\tilde{x})$. To prove *ii*), first take the derivative of $G(\tilde{x})$ and solve for $\tilde{x}$.

$$
\begin{aligned}
\frac{dG(\tilde{x})}{d\tilde{x}} &= \frac{1}{2}\frac{d\mathrm{erf}(\tilde{x})}{d\tilde{x}} + \frac{2\tilde{x}}{\gamma\sigma\sqrt{2\pi}}e^{-\tilde{x}^2} \\
&= \left(\frac{1}{\sqrt{\pi}} + \frac{\tilde{x}}{\gamma\sigma}\sqrt{\frac{2}{\pi}}\right)e^{-\tilde{x}^2} = 0.
\end{aligned}
$$

Solving for $\tilde{x}$ results in

$$\check{x} = -\frac{\gamma\sigma}{\sqrt{2}},$$

which implies that $G(\tilde{x})$ reaches its minimum when $p_1 = \mu$.

We can approximate the value of $\tilde{x}$ such that $G(\tilde{x}) = 0$ by taking a first order Taylor approximation of the error function and exponent in the expression for $G(\tilde{x})$: $\mathrm{erf}(\tilde{x}) = 2\tilde{x}/\sqrt{\pi}$ and $e^{-\tilde{x}^2} = 1-\tilde{x}^2$. This leads to

$$\frac{\sqrt{\pi}}{2} + \tilde{x} = \frac{1-\tilde{x}^2}{\gamma\sigma\sqrt{2}}.$$

Solving for $\tilde{x}$ gives

$$\tilde{x} = -\frac{\gamma\sigma}{\sqrt{2}} + \sqrt{\frac{(\gamma\sigma)^2 - \sqrt{2\pi}\gamma\sigma + 2}{2}} = \check{x} + \sqrt{\frac{(\gamma\sigma)^2 - \sqrt{2\pi}\gamma\sigma + 2}{2}}. \tag{A.13}$$

The negative root is irrelevant because it is to the left of $\check{x}$. The corresponding approximate value for p_1^R is

$$\hat{p}_1^R = \mu + \sigma\sqrt{(\gamma\sigma)^2 - \gamma\sigma\sqrt{2\pi} + 2}.$$

This completes the proof. $\square$.

A.3 Proof of Proposition 3

Consider a loss-averse agent with linear consumption utility, loss-aversion parameter λ, and weight η attached to the linear gain-loss utility with the currently best price p_1 acting as a reference point.[27] Let s be the cost of observing one more price and let these prices p be drawn out of a $N(\mu, \sigma)$ distribution.

Then, the utility when the agent with wealth w stops searching is

$$u(\text{Stop}|p_1) = w - p_1.$$

The utility from continued search equals:

$$\begin{aligned} u(\text{Continue}|p_1) &= w - p_1 - s + P(p \le p_1)E[p_1 - p|p \le p_1] + \eta\left[P(p \le p_1 - s)E[p_1 - p - s|p \le p_1 - s]\right. \\ &\quad \left. -\lambda\left\{P(p_1 - s < p \le p_1)E[p - p_1|p_1 - s < p \le p_1] + sP(p > p_1 - s)\right\}\right]. \\ &= -p_1 + \tilde{\eta}\Big[P(p \le p_1 - s)E[p_1 - p - s|p \le p_1 - s] \\ &\quad -\tilde{\lambda}\left\{P(p_1 - s < p \le p_1)E[p - p_1|p_1 - s < p \le p_1] + sP(p > p_1 - s)\right\}\Big] \end{aligned}$$

with $\tilde{\eta} \equiv \eta + 1$ and $\tilde{\lambda} \equiv (\eta\lambda + 1)/(\eta + 1)$ such that $\tilde{\eta}\tilde{\lambda} = (\eta\lambda + 1)$. In what follows we normalize $\eta = 1$ such that $\tilde{\eta} = 2$ and $\lambda = (2\tilde{\lambda} - 1)$. Note that $\tilde{\lambda} = 1$ iff. $\lambda = 1$.

Define $\alpha \equiv (p_1 - \mu)/\sigma$ and $\beta \equiv (p_1 - s - \mu)/\sigma$ ($\beta < \alpha$ iff. $s > 0$); we denote the p.d.f. of the standard normal distribution as $\phi(x) = \frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}x^2}$ and its c.d.f. $\Phi(\cdot)$.

Using these definitions, one can write

$$E[p|p_1 - s < p \le p_1] = \mu + \frac{\phi(\beta) - \phi(\alpha)}{\Phi(\alpha) - \Phi(\beta)}\sigma \quad \text{and}$$

$$E[p|p \le p_1 - s] = \mu - \sigma\frac{\phi(\beta)}{\Phi(\beta)}.$$

[27] We assume that the agent's utility of consuming the good exceeds p_1 in all cases such that she buys in all cases and we for this reason can ignore it in the decision whether or not to continue search.

So, the agent is indifferent when $u(\text{Stop}) = u(\text{Continue})$, i.e. when

$$\begin{aligned} & p_1\left\{\Phi(\beta)+\tilde{\lambda}[\Phi(\alpha)-\Phi(\beta)]\right\}-\Phi(\beta)\left[\mu-\sigma\frac{\phi(\beta)}{\Phi(\beta)}\right]-\tilde{\lambda}[\Phi(\alpha)-\Phi(\beta)]\left[\mu+\frac{\phi(\beta)-\phi(\alpha)}{\Phi(\alpha)-\Phi(\beta)}\sigma\right] \\ = \; & s[\Phi(\beta)+\tilde{\lambda}(1-\Phi(\beta))] \end{aligned}$$

which can be simplified to:[28]

$$\begin{aligned} & p_1\left\{\Phi(\beta)+\tilde{\lambda}[\Phi(\alpha)-\Phi(\beta)]\right\}-\mu[\tilde{\lambda}\Phi(\alpha)+(1-\tilde{\lambda})\Phi(\beta)]+\tilde{\lambda}\phi(\alpha)\sigma-(\tilde{\lambda}-1)\phi(\beta)\sigma \\ = \; & \tilde{\lambda}s+(1-\tilde{\lambda})s\Phi(\beta). \end{aligned}$$

After combining terms, we have:

$$f(\sigma,s) \equiv \tilde{\lambda}(p_1-\mu)\Phi(\alpha)+(1-\tilde{\lambda})(p_1-\mu-s)\Phi(\beta)+\tilde{\lambda}\phi(\alpha)\sigma-(\tilde{\lambda}-1)\phi(\beta)\sigma-\tilde{\lambda}s=0.$$

This equation implicitly defines s^* such that $f(\sigma, s^*) = 0$, the search cost that makes the agent indifferent between stopping and continuing search conditional on the best observed price being p_1. Next we take the partial derivative of $f(\sigma, s)$ with respect to s and σ and use the implicit function theorem to determine $ds^*/d\sigma$.

$$\begin{aligned} \frac{\partial f(\sigma,s)}{\partial\sigma} &= \tilde{\lambda}(p_1-\mu)\frac{\partial\Phi(\alpha)}{\partial\sigma}+(1-\tilde{\lambda})(p_1-\mu-s)\frac{\partial\Phi(\beta)}{\partial\sigma}+\tilde{\lambda}\left[\phi(\alpha)+\sigma\frac{\partial\phi(\alpha)}{\partial\sigma}\right] \\ &- (\tilde{\lambda}-1)\left[\phi(\beta)+\sigma\frac{\partial\phi(\beta)}{\partial\sigma}\right] \\ &= -\tilde{\lambda}\left(\frac{p_1-\mu}{\sigma}\right)^2\frac{\partial\Phi(\alpha)}{\partial\alpha}-(1-\tilde{\lambda})\left(\frac{p_1-\mu-s}{\sigma}\right)^2\frac{\partial\Phi(\beta)}{\partial\beta} \\ &+ \tilde{\lambda}\left[\phi(\alpha)+\sigma\frac{\partial\phi(\alpha)}{\partial\alpha}\right]-(\tilde{\lambda}-1)\left[\phi(\beta)+\sigma\frac{\partial\phi(\beta)}{\partial\beta}\right] \\ &= -\tilde{\lambda}\alpha^2\phi(\alpha)+\tilde{\lambda}(1+\alpha^2)\phi(\alpha)-(1-\tilde{\lambda})\beta^2\phi(\beta)+(1-\tilde{\lambda})(1+\beta^2)\phi(\beta) \\ &= \tilde{\lambda}\phi(\alpha)+(1-\tilde{\lambda})\phi(\beta). \end{aligned}$$

The penultimate equation follows because $\phi(x)+\sigma\frac{\partial\phi(x)}{\partial x} = (1+x^2)\phi(x)$.

$$\begin{aligned} \frac{\partial f(\sigma,s)}{\partial s} &= -(1-\tilde{\lambda})\Phi(\beta)+(1-\tilde{\lambda})(p_1-\mu-s)\frac{\partial\Phi(\beta)}{\partial s}-(\tilde{\lambda}-1)\frac{\partial\phi(\beta)}{\partial s}\sigma-\tilde{\lambda} \\ &= -(1-\tilde{\lambda})\Phi(\beta)-(1-\tilde{\lambda})(p_1-\mu-s)\frac{\phi(\beta)}{\sigma}+(\tilde{\lambda}-1)\frac{\partial\phi(\beta)}{\partial\beta}\cdot\frac{1}{\sigma}\cdot\sigma-\tilde{\lambda} \\ &= \tilde{\lambda}(\Phi(\beta)-1)-\Phi(\beta). \end{aligned}$$

[28] For $\tilde{\lambda} = 1$ the equation reduces to the familiar condition $p_1 - E[\min(p, p_1)] = s$.

We apply the implicit function theorem using the previous two expressions and find

$$\frac{ds^*}{d\sigma} = -\frac{\partial f/\partial \sigma}{\partial f/\partial s} = -\left(\frac{\tilde{\lambda}\phi(\alpha) + (1-\tilde{\lambda})\phi(\beta)}{\tilde{\lambda}(\Phi(\beta)-1) - \Phi(\beta)}\right). \tag{A.14}$$

Consistent with Proposition 1, $\partial s^*/\partial \sigma = \phi(\alpha) \geq 0$ for $\tilde{\lambda} = 1$. The denominator is negative for all $\tilde{\lambda} > 1$ and decreasing in $\tilde{\lambda}$ because $\Phi(\beta) < 1$ in the relevant price range when the search cost $s > 0$. So, $\partial s^*/\partial \sigma = 0$ if and only if

$$\tilde{\lambda}\phi(\alpha) + (1-\tilde{\lambda})\phi(\beta) = 0 \Rightarrow \tilde{\lambda} = \frac{\phi(\beta)}{\phi(\beta) - \phi(\alpha)} \geq 1. \tag{A.15}$$

Using $\alpha \equiv (p_1 - \mu)/\sigma)$ and $\beta \equiv (p_1 - s^* - \mu)/\sigma)$ and simplifying, we have that

$$\frac{\phi(\beta)}{\phi(\beta) - \phi(\alpha)} = \frac{1}{1 - e^{-\frac{s^*}{\sigma^2}(p_1 - \mu - s^*/2)}}.$$

Inserting this in (A.15) and solving for p_1, we obtain

$$p_1^L = \mu + \frac{s^*}{2} + \frac{\sigma^2}{s^*} \ln\left(\frac{\tilde{\lambda}}{\tilde{\lambda} - 1}\right).$$

$\partial s^*/\partial \sigma > 0 (< 0)$ for $p_1 < (>) p_1^L$. In this equation, the willingness to pay $s^* > 0$ is endogenous. But because prices are non-negative, s^* is always finite such that $\lim_{\tilde{\lambda}\downarrow 1} p_1^L \uparrow +\infty$. $\square$.

B Additional Tables

Table B.1: Order in which situations were presented

	Order				
Program	(*i*)	(*ii*)	(*iii*)	(*iv*)	**Total**
Economics and Business	36	39	36	35	**146**
Econometrics	22	20	17	20	**79**
Pre-MSc	13	12	9	12	**46**
Minor Finance	2	3	4	3	**12**
Total	**73**	**74**	**66**	**70**	**283**

Note: The orders are $(i) = p_L s_H - p_L s_L - p_H s_H - p_H s_L$; $(ii) = p_L s_L - p_L s_H - p_H s_L - p_H s_H$; $(iii) = p_H s_H - p_H s_L - p_L s_H - p_L s_L$; $(iv) = p_H s_L - p_H s_H - p_L s_L - p_L s_H$.

C Survey

General instructions

This is a short survey for research purposes. Please read the instructions carefully. On the next pages, we will describe four situations. In each situation, we will ask you to write down what you would do if you were in that particular situation. However, first we give an example of the situations you fill face.

EXAMPLE: You wish to buy a certain product. The firm you have just visited offers this product at a price of €10. There are 100 other firms that offer exactly the same product. You know that one of these firms charges a price of €1, four charge a price of €3, eleven charge a price of €5 etc. This information is summarized in Figure C.1 (the current price of €10 is shown by the dotted vertical line). Unfortunately you don't know which firm charges what price.

You face the following choice between options **a)** and **b)**:

a) buy the product from the firm you have just visited at this firm's price of €10.

b) pay an amount to visit one randomly selected firm out the 100 other firms to see whether this firm offers you the product at a better price.

Important note: If you choose **b)**, you still have to the option to buy the product at €10 from the first firm, should the second firm be more expensive. If the second firm charges a price lower than €10, you can of course buy the product at this lower price.

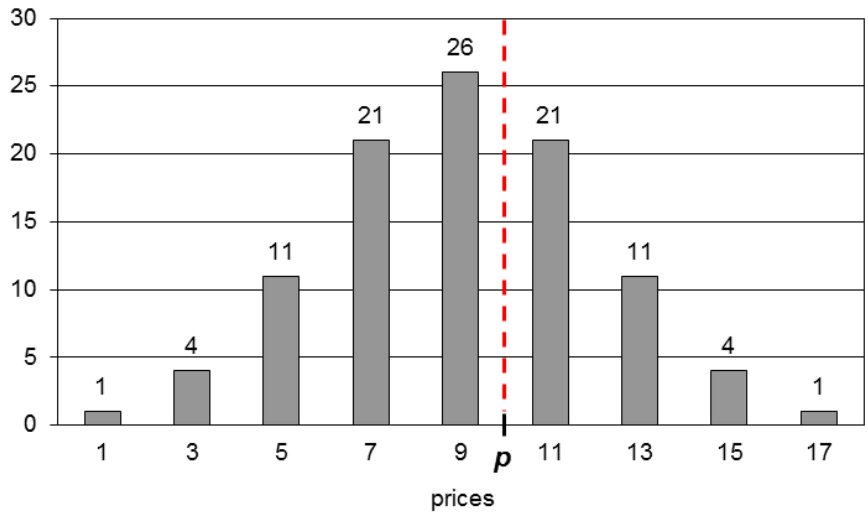

Figure C.1: 100 firms. The bars denote the number of firms that charges a given price. The firm you have just visited offers this product at a price of €10.

In each situation, we ask you to answer the following question:

What is the maximum amount you would be willing to pay to see the price of a second firm? [please fill in a non-negative number with two digits] €________

If you prefer option **a)**, you should fill in "€0.00". This means that you are not willing to pay anything to observe the price of the second retailer. If you prefer option **b)**, you should indicate the maximum amount you would be willing to pay.

When answering the questions, you may go back and forth between situations but you are not allowed to discuss with any other person in the room.

Situations

The general instructions were followed by four specific situations. The situations differed only in the price distribution and the given price p. The four situations are depicted in Figure 3. We only present the text that accompanied Figure 3a, the price distribution in Situation 1, the texts for Situations 2 to 4 were similar.

Situation 1

You wish to buy a certain product. The firm you have just visited offers this product at a price of €10. There are 100 other firms that offer exactly the same product. You know that two of these firms charge a price of €5, five charge a price of €7, eight charge a price of €9 etc. This information is summarized in the figure above (the current price of €10 is shown by the dotted vertical line).

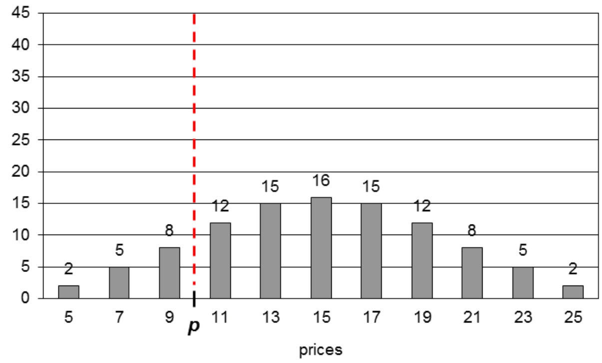

Figure C.2: Situation 1. 100 firms. The bars denote the number of firms that charges a given price. The firm you have just visited offers this product at a price of €10.

Unfortunately you don't know which firm charges what price.

Now you have to decide:

a) buy the product from the firm you have just visited at this firm's price of €10.

b) pay an amount to visit one randomly selected firm out the 100 other firms to see whether this firm offers you the product at a better price.

Important note: If you choose **b)**, you still have to the option to buy the product at €10 from the first firm, should the second firm be more expensive. If the second firm charges a price lower than €10, you can of course buy the product at this lower price.

What is the maximum amount you would be willing to pay to see the price of a second firm? [please fill in a non-negative number with two digits] €_______